

GROWTH PATTERN OF PICAREL, *SPICARA SMARIS* (L.) (CENTRACANTHIDAE), A PROTOGYNOUS SPECIES

by

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ABSTRACT. - Some problems involved in the study of the growth of picarel, *Spicara smaris* (L.), are presented and discussed. Three growth models have been applied including a new one incorporating aspects of the sex reversal of the species. The growth curve of *S. smaris* is characterized by a pattern which seems to be ruled by the sex change of the individuals. Among the models tested, the new model fits the data best. All models applied suggest high K values and L_{inf} values smaller than the maximum length recorded.

RÉSUMÉ. - Quelques problèmes relatifs aux modèles de croissance du picarel, *Spicara smaris* (L.), sont présentés et discutés. Trois modèles de croissance ont été appliqués, y compris un nouveau modèle qui incorpore des aspects du changement de sexe pour cette espèce. La courbe de croissance de *S. smaris* est caractérisée par un modèle qui semble être gouverné par le changement du sexe des individus. Parmi les modèles testés, le nouveau modèle s'accorde le mieux avec nos données. Tous les modèles indiquent de hautes valeurs de K, et des valeurs de L_{inf} plus basses que la longueur maximum observée.

Key-words. - Centranchidae, *Spicara smaris*, MED, Greece, Spawning behaviour, Sex reversal, Growth model, Otolith ageing.

Spicara smaris (L.) (picarel) is a little known species although very common in the Mediterranean basin. It is also found near the coasts of the Black Sea, Portugal, Morocco and the Canaries, inhabiting *Posidonia* beds and muddy bottoms at about 15-170 m. (Palombi and Santarelli, 1979; Riedl, 1986; Whitehead *et al.*, 1986; Fisher *et al.*, 1987).

S. smaris belongs to the family Centranchidae, lives up to four, perhaps five years and has a maximum length of about 21 cm. It is a protogynous species (Zei, 1949; Salekhova, 1979) and may be considered as a shoaling fish although not typical. The fish spend most of their life cycle in schools but during breeding their behaviour is significantly differentiated. The spawning grounds are vast and extend on detritic sandy bottom from the deep border of the *Posidonia oceanica* (L.) beds (Harmelin and Harmelin-Vivien, 1976). The nests are excavated edge to edge and each is actively guarded by a brightly coloured male. The females and some males swim above the nest area. At the end of the incubation of the eggs, the males lose their coloration, group themselves into large schools and swim away to feeding places. Similar observations have been made on the Black Sea *S. smaris* by Darkov and Mochek (1979).

Although there are ample data dealing with aspects of the physiology of the *S. smaris* (Alekseeva, 1977; Kotov, 1977; Khotkevich, 1978; Korolev *et al.*, 1978; Ehmeretli, 1981; Uskova *et al.*, 1982), very little is known about the growth pattern of

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this species. Scattered data exist from France (Passelaigue, 1974) and Greece (Tsangridis and Filippousis, 1989, 1991), based on otolith readings and length analysis, respectively.

This paper presents a study of the growth pattern of the *S. smaris* and suggests a new growth model which incorporates aspects of the sex reversal of the species.

MATERIALS AND METHODS

S. smaris is a short lived, fast growing species with a spawning period restricted to April-May (in the area studied; Tsangridis and Filippousis, 1989). Therefore, we considered that *S. smaris* growth should be better studied in quarterly fractions of the year, allocating a birthday on the 1st of May.

Samples were taken at random from motorized 90 HP beach seiners' fresh landings of *S. smaris* on Salamina island fish market, Saronikos Gulf off Athens, Greece (Fig. 1) and cover the period May 1988 - May 1990 at quarterly intervals. The cod-end mesh size of beach seiners is 8 mm between stretched knots.

One sample consisting solely of juveniles was examined in November 1989 to obtain better estimates of the 0.50 age group. Extra samples in May 1989 and May 1990 aiming to obtain better estimates of the mean lengths at age 2.0, 3.0, and 4.0, were also taken -at random- from the same landings, consisting solely of male fish.

A cod-end of 6 mm between stretched knots was used in trial samplings (with beach seiner) in August 1988 to catch the 0.25 age group.

3754 fish were measured fresh and their total length was recorded in mm. The length frequency distributions were determined using 5 mm class intervals. Samples of up to 10 individuals per 5 mm interval throughout the available length range were retained for biological examination (1155 fish were examined in total). Each fish in the retained sample was measured to the nearest mm below. A note was made on the sex and state of maturity. The sagittal otoliths were extracted, cleaned in fresh water and then stored in neutralized glycerine in small plastic tubes. During the summer the otoliths were stored in freezers to avoid degradation and dissolution. Cool, dark storage areas were selected



Fig. 1. - Map of the Saronikos Gulf (Athens, Greece), showing Salamina island.

during the other seasons of the year. The otolith integrity was occasionally checked to avoid bias in age reading.

Otoliths were read with reflected light on a black background, in glycerine, using a WILD M8 binocular stereoscope. The mean length of each age group was calculated by taking the arithmetical average of the estimates for each season of each year. The estimates for each season were determined by raising age-length keys by the corresponding fish length distributions.

Thus, the estimate for e.g. one year old fish, was taken by the formula:

$$L = \frac{l + l' + l''}{3}$$

where l , l' , l'' are the estimates of mean lengths at age 1.0 in May 1988, May 1989, May 1990 respectively. The estimates for age groups 2.0, 3.0 and 4.0 were calculated by pooling all the age-length keys data for each age group and taking the simple arithmetical mean. Taking in mind the peculiar behaviour of *S. smaris* during breeding, this seems to be a more realistic way of estimating the mean lengths at ages 2.0, 3.0 and 4.0, provided that male samples are available. (Our estimates for age 2.0 were based on 23 KK and 95 ♂♂; for age 3.0, 100 KK and 22 ♂♂; for age 4.0, 32 KK). The final estimates (Table I) for each age group were considered as equally weighted in every growth model.

The models applied are:

1. The von Bertalanffy growth function model (VB):

$$L_t = L_{inf} / [1 - \exp\{-K(t - t_0)\}]$$

where L_t is the length at t years of age, L_{inf} is the asymptotic length, K a growth constant, and t_0 the age at zero length.

Table I. - Age groups of *Spicara smaris* and corresponding sampling months with the estimates of mean length and the proportion of males in each age group. (*): Despite our efforts, we did not succeed to catch adult individuals in August; therefore, the mean lengths in the 1.25, 2.25 and 3.25 age groups are lacking.

Age group (years)	Sampling month	Mean length at age (mm)	Proportion of males
0.25	August (*)	62	0.00
0.50	November	106	0.00
0.75	February	139	0.00
1.00	May	139	0.06
1.50	November	144	0.06
1.75	February	153	0.17
2.00	May	159	0.20
2.50	November	160	0.40
2.75	February	170	0.73
3.00	May	184	0.80
3.50	November	180	0.82
3.75	February	187	0.83
4.00	May	199	1.00

2. The Somers (1988) oscillating growth function model (SO):

$$L_t = L_{inf} \left\{ 1 - \exp[-K(t - t_0)] - \frac{CK}{2\pi} (\sin 2\pi(t - t_s) - \sin 2\pi(t_0 - t_s)) \right\}$$

where C determines the amplitude of the oscillation and t_s sets the beginning of the sine wave. The other parameters are defined as in the (VB) model.

3. A new model, incorporating aspects of the sex reversal of the species studied (SR):

$$L_t = (qL_F + pL_M) \{ 1 - \exp[-(qK_F + pK_M)(t - t_0)] \}$$

where L_F is the asymptotic length for females, L_M is the asymptotic length for males, K_F is the growth constant for females, K_M is the growth constant for males, p is the proportion of males per age group and $q = 1 - p$.

This new model is based on the standard von Bertalanffy growth function (VB) and takes into account the fact that the *S. smarís* is a protogynous species. In this model, the pseudo-migration of males during breeding causes difficulties in the determination of male proportions at the ages 2.0 and 3.0. The percentages assigned to these age groups have been chosen -although arbitrary- on the basis of the percentages observed at the ages 1.75 and 2.75. The proportion of males at the age 2.50, according to our observations, was 14.3%, which is very low since at the age 2.75 it is recorded as 73%. In our trials it was taken as 40% on the assumption that the period when females are most likely to change into males is between 2.0 and 2.50 years. Two more trials were done taking the proportion of males at the age 2.50 as 50% and 60%.

These three models were fitted using non-linear fitting techniques. Simplex subroutines were followed to fit our models (Cook, 1987) and the software used was developed by Cook. The software package "Micro-simplex nonlinear estimation package" developed by Schnute was also used for verification purposes (Schnute, pers. comm.).

The plotting of cumulative sums (CUSUM) of residuals of each model was used to examine the best fit among the models applied (cf. Nicholson, 1984).

The von Bertalanffy model was also examined following a versatile linear regression approach (SC method) recently presented by Stamatopoulos and Caddy (1989), who developed the software programme used in our trials. They follow simple linear regression but, in their approach, the driving parameter is the K growth constant.

RESULTS

The length frequency distributions of *S. smarís* measured at Salamina fish market, from May 1988 to May 1990, are shown in figure 2.

There are no particular problems in reading otoliths of *S. smarís*. Most otoliths showed clearly defined opaque and hyaline zones under reflected light. Annual rings occur in late May.

The estimates of the growth parameters of *S. smarís* depend on the model applied. The values estimated are summarized in table II and the curves fitted are shown in figures 3 to 5. The micro-simplex nonlinear estimation software package used by Schnute to fit the models examined to our data verified our estimates and results.

The plotting of cumulative sums of residuals of the three, non-linear models tested, is given in figure 6. It appears that the (SR) model fits better to our length at age data.

The (SO) model cannot be accepted since it gives senseless values for the C parameter ($C = 3.389$).

It seems that the proportion of males at the age 2.50 has no significant effect on the estimates of growth parameters in the (SR) model (Table III).

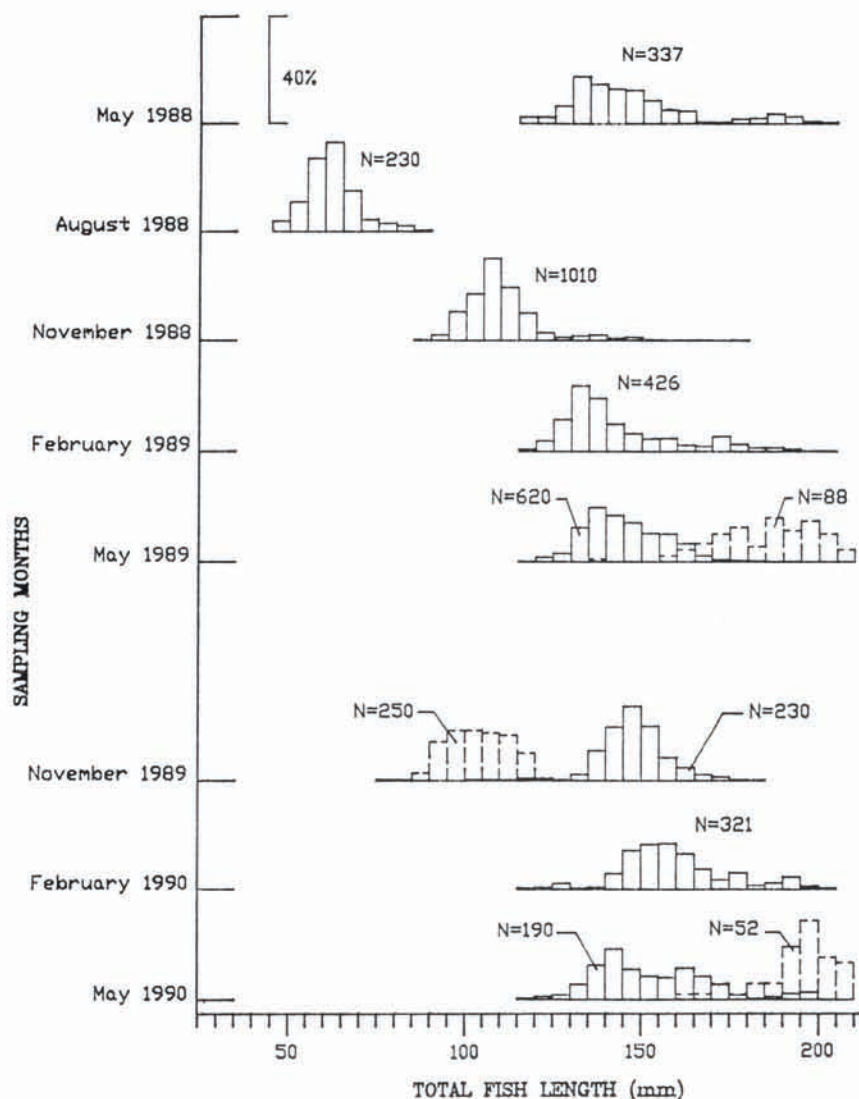


Fig. 2. - Percentage frequency distributions of total length of *Spicara smaris* in samples measured at Salamina island fish market. Data from the Saronikos Gulf, Athens, Greece; May 1988 - May 1990. (Dashed lines in May 1989 and May 1990 represent the length distributions of extra samples consisting solely of male fish. Dashed line in November 1989 corresponds to the length distribution of juveniles).

DISCUSSION

Sex reversal and differentiated behaviour during breeding cause the greatest difficulties in the study of *S. smaris* growth (cf. Salekhova, 1979).

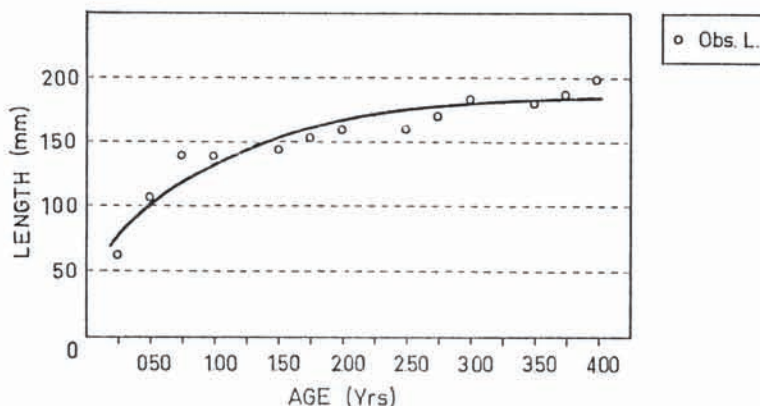


Fig. 3. - Application of the von Bertalanffy (VB) growth model to the length at age data and fitted growth curve of *Spicara smaris*. Data from the Saronikos Gulf, Athens, Greece; May 1988 - May 1990.

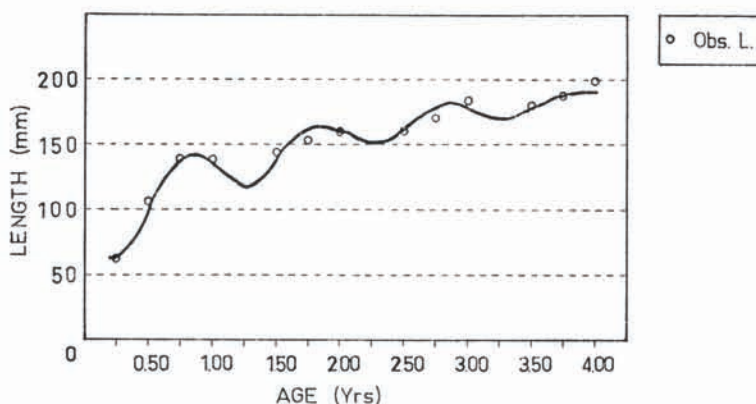


Fig. 4. - Application of the Somers (SO) growth model to the length at age data and fitted growth curve of *Spicara smaris*. Data from the Saronikos Gulf, Athens, Greece; May 1988 - May 1990.

The mean lengths at age estimated for each sex indicate a difference in growth rates between females and males (Fig. 7). Fitting two separate curves is, however, incompatible with the sequential hermaphroditism of *S. smaris* and cannot be considered as a reasonable interpretation.

We note that males are generally larger than females and it is very likely that the reproductive habits of *S. smaris*, such as the nest building by males, effect these differences between the sexes (cf. Lagler *et al.*, 1977).

Inspection of the mean lengths at age (Table I) indicates slow growth during summer and relatively fast growth during winter time. This is probably due to the timing of the *S. smaris* sexual maturity, since it is known that fish growth usually slows down after the onset of sexual maturity (Lagler *et al.*, 1977). Sex change of *S. smaris*, occurring during the summer period (Salekhova, 1979), immediately after spawning, is possibly an additional reason for the slower growth during summer.

Table II. - Estimates of growth parameters of *Spicara smaris* according to the models applied. (VB): von Bertalanffy; (SO): Somers; (SR): Sex Reversal; (SC): Stamatopoulos and Caddy. Figures between square brackets represent the standard deviation. RSS (*): Residual sum of squares.

	Non linear fit			Linear fit
	(VB)	(SO)	(SR)	(SC)
L_{inf} (mm)	187.3 [8.105]	205.9 [9.823]	144.6 (♀) [2.9] 192.7 (♂) [2.592] 3.616 (♀) [0.518]	187.3
K	0.929 [0.256]	0.467 [0.094]	1.562 (♂) [0.868]	0.929
t_0	-0.317 [0.192]	-0.624 [0.067]	0.098 [0.026]	-0.316
C	-	3.389 [0.791]	-	-
t_s	-	0.548 [0.020]	-	-
Coef. Dt.	0.913	0.972	0.982	0.913
RSS (*)	1420.23	456.87	290.98	1420.23

The mean lengths observed imply some kind of oscillation in the growth pattern of *S. smaris* and that is the most likely reason for the poorest fit of (VB) model to our data (Figs 3, 6). The (SO) seasonally oscillating model (Table II, Fig. 4) produces, however, erroneous estimate of the C parameter ($C = 3.389$). Since the software programme avoids the acceptance of a "wrong" model to fit the data by giving senseless values (Cook, pers. comm.), the (SO) model cannot be accepted. The reason is that the oscillating curve tries to make growth oscillate in the same way within each year; our data do not really do this and they "oscillate" as the fish change sex which takes place over a number of years (Cook, pers. comm.). When plotting the fitted values the curve goes through the data reasonably well but some of the points actually predict that the fish shrink at certain ages (Fig. 4).

It is interesting to note that the mean lengths observed form two -although not well defined- plateaux (e.g. Fig. 5); one occurs at lengths around 150 mm (between ages 1.0 - 2.0) and the other at lengths around 180 mm (between ages 3.0 - 4.0). These two plateaux may be due to the sex change of this species for it is known that sex reversal occurs mainly around the age of 2.0 years (cf. Salekhova, 1979).

We note that among the models tested, the (SR) model (Fig. 5) produces the lowest residual sum of squares (Table II) and shows the best fitting according to the CUSUM technique (Fig. 6). The estimates of K parameters computed by this model are very high and differ according to sex, suggesting different growth rates for females ($K = 3.616$) and males ($K = 1.562$). The value of K, particularly in females, is extremely high; however, it may be accepted if we take into account the fast growth of this species. Females have a life span of between two and three years and at the age of three months they reach a mean length of 62 mm, which is 43% of their asymptotic length. At six

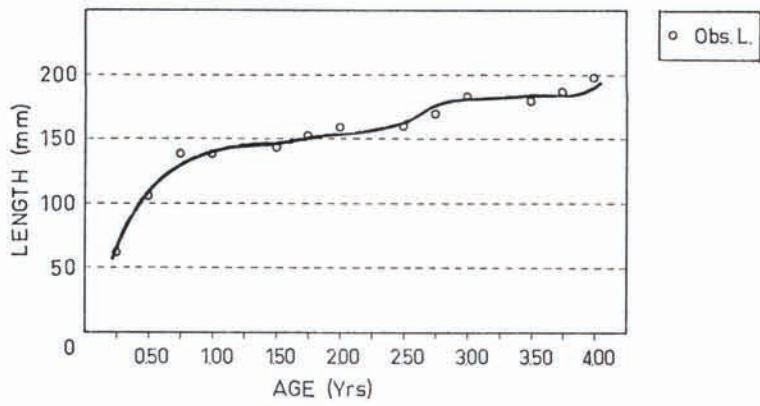


Fig. 5. - Application of the Sex Reversal (SR) growth model to the length at age data and fitted growth curve of *Spicara smaris*. Data from the Saronikos Gulf, Athens, Greece; May 1988 - May 1990.

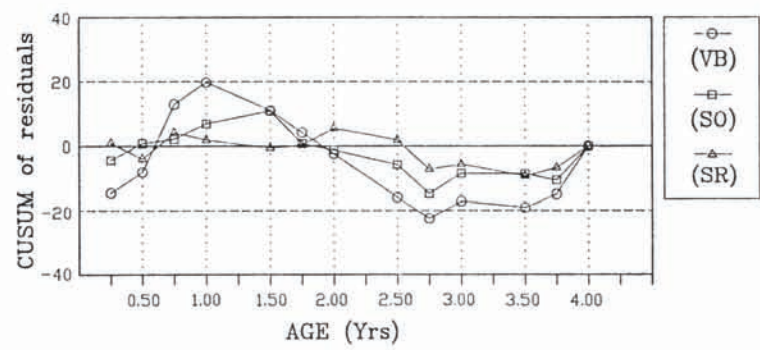


Fig. 6. - Plotting of cumulative sums (CUSUM) of residuals of the growth models examined [(VB): von Bertalanffy; (SO): Somers ; (SR): Sex Reversal], applied to the length at age data of *Spicara smaris*. Data from the Saronikos Gulf, Athens, Greece; May 1988 - May 1990.

	Proportion of males		
	40 %	50 %	60 %
L _{inf} (F)	144.6	144.2	144.4
K(F)	3.616	3.665	3.622
L _{inf} (M)	192.7	192.0	191.2
K(M)	1.562	1.608	1.526
t ₀	0.098	0.099	0.098
Coef. Dt.	0.982	0.979	0.973

Table III. - Growth parameters of *Spicara smaris*, computed by the Sex Reversal growth model with different proportions of males assigned to the 2.50 age group. Lengths are recorded in mm.

months, their mean length is 73% of the asymptotic length and within a year, it is close to 96%.

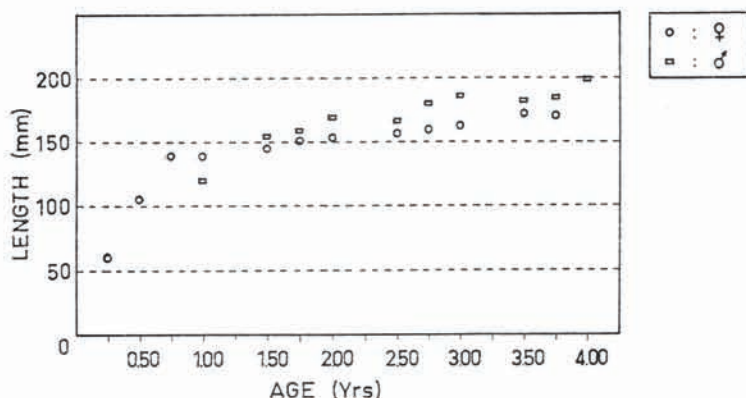


Fig. 7. - Mean length at age for female and male individuals of *Spicara smaris*. Data from the Saronikos Gulf, Athens, Greece; May 1988 - May 1990.

The results taken by the linear regression approach (SC method), which was proposed by Stamatopoulos and Caddy (1989), coincide with those taken by the non-linear fit of the (VB) model (Table II). These authors note that the advantage of their approach over non-linear procedures is that K is the ruling parameter and the optimization process deals with points on a curve rather than on a surface. The fact, however, that linear regression connects things that are not linearly related cannot be neglected. Besides, where the parameters are non-linearly related, as for example in the von Bertalanffy growth curve, it is very difficult to obtain explicit solutions (Cook, 1987; Hoenig and Hanumara, 1990).

The results from all models applied (Table II) indicate very high K values and L_{inf} values smaller than the maximum length recorded ($L_{max} = 209$ mm). Use of length-data also indicates high K values for *S. smaris* (Tsangridis and Filippousis, 1989, 1991). Computation of smaller L_{inf} values are due to the fast growth of *S. smaris* (cf. Jones, 1984) and variations in the estimates depend on the model applied.

To sum up, there is evidence that the growth curve of the *S. smaris* is characterized by an oscillating pattern which seems to be ruled by the sex change of the species. It appears that there are two oscillations which correspond to two different growth periods. The first one applies to an early, very fast, female growth period leading to mature females with a length of about 150 mm. This is followed by a second period of male growth with relatively slow growth, leading to mature males with a length of about 190 mm.

The (SR) model, besides a good fit and reasonable estimates, incorporates aspects of the *S. smaris* sequential hermaphroditism, and this is an advantage over the known models. We must, however, emphasize the fact that this model is simply an alternative aspect aiming at a better description of the *S. smaris* growth pattern. It is known that modelling fish growth is not an easy task: besides mathematics, it requires inputs from all fields of biology (cf. Pitcher and Macdonald, 1973; Cook, 1987; Moreau, 1987; Somers, 1988).

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